

# 1 PLANT FERTILIZER COMPOSITIONS CONTAINING PHOSPHONATE AND PHOSPHATE SALTS AND DERIVATIVES THEREOF

## CROSS REFERENCE TO RELATED APPLICATIONS

This application is a division of [co-pending U.S. patent application] Ser. No. 08/812,865, filed Mar. 6, 1997. U.S. Pat. No. 5,800,837, issued Sep. 1, 1998, which is a C-I-P of U.S. Ser. No. 08/705,594, filed Aug. 30, 1996. U.S. Pat. No. 5,736,164, issued Apr. 7, 1998.

## BACKGROUND OF THE INVENTION

The present invention is broadly concerned with fungicidal compositions, and methods of use, which provide improved efficacy in controlling parasitic fungi in plants. More particularly, the compositions and methods of use of the invention include fungicidally effective amounts of both phosphate, preferably in the form of either mono, di, tri or dipotassium phosphate ( $\text{KH}_2\text{PO}_4$ ,  $\text{K}_2\text{HPO}_4$ ) and phosphonate, preferably in the form of either mono or dipotassium phosphonate ( $\text{KH}_2\text{PO}_3$ ,  $\text{K}_2\text{HPO}_3$ ), in aqueous solution.

According to another aspect of the present invention, the compositions and methods of use of the invention include growth response effective amounts of both phosphate, preferably in the form of either mono or dipotassium phosphate ( $\text{KH}_2\text{PO}_4$ ,  $\text{K}_2\text{HPO}_4$ ) and phosphonate, preferably in the form of either mono or dipotassium phosphonate ( $\text{KH}_2\text{PO}_3$ ,  $\text{K}_2\text{HPO}_3$ ), in aqueous solution.

Phosphorus is an essential major element in plant nutrition because it governs the energy producing reactions, including those that are oxidative, and photophosphorylative and the production of adenosine diphosphate (ADP) and adenosine triphosphate (ATP). Energy-rich phosphate bonds of ADP and ATP provide the energy for many of the physiological reactions that occur in plants.

The element phosphorous appears in two general forms that concern the present invention—phosphonate and phosphate. The term "phosphonate," sometimes also referred to as "phosphite," means the salts (organic or inorganic) of either phosphonic acid or phosphorous acid. Phosphonic and phosphorous acids have the formula  $\text{H}_3\text{PO}_3$  and a molecular weight of 82.00. Their structures from the International Union of Pure and Applied Chemistry are shown below:



Phosphonic Acid  
CA: 13598-36-2



Phosphorous Acid  
CA: 10294-56-1

The term "phosphate" means the salts (organic or inorganic) of phosphoric acid having the formula  $\text{H}_3\text{PO}_4$ , molecular weight of 98, and has the following structure:



Phosphoric Acid  
CA: 7664-38-2

In the past, various phosphonate compounds have been proposed as useful in fungicidal and fertilizer compositions for application to plants. See, e.g., U.S. Pat. Nos. 4,075,324 and 4,119,724 to Thizy, describing phosphorous acid, its inorganic and organic salts, as a plant fungicide; U.S. Pat. No. 4,139,616 to Dueret, describing fungicidal compositions based on phosphorous acid esters and salts thereof; U.S. Pat. No. 4,542,023 to Lacroix et al., describing organophosphorus derivatives as possessing systemic and contact fungistatic and fungicidal activity; U.S. Pat. Nos. 4,698,334 and 4,806,445 and 5,169,646 to Horriere et al., describing fungicidal compositions based on alkyl phosphonates; U.S. Pat. Nos. 4,935,410 and 5,070,083 to Barlet, describing fungicidal aluminum tri-alkyl-phosphonate compositions; and U.S. Pat. No. 5,514,200 to Lovatt, describing formulations of phosphorous-containing acid fertilizer for plants. (The teachings of the preceding U.S. Patents are hereby incorporated by reference.) The above references disclose phosphonate compositions have been found to be effective for protecting plants, and particularly grape vines, citrus and fruit trees and tropical plants, against fungal attack.

Once assimilated, phosphonates have been shown to enhance the phytoimmune system. The phosphonate induced stimulation of the phytoimmune system is triggered by the induction of ethylene production, followed by a rapid accumulation of phytoalexins at the site of infection. Phosphonates have also been shown to have detrimental effect on the growth of Phycomycetes. See, Pegg, K. G. and deBoer, R. F., "Proceedings of the Phosphonic (Phosphorous) Acid Work Shop," *Australasian Plant Pathology*, Vol. 19 (4) 1990.

In accordance with this development of the present invention, however, it has recently been discovered that phosphonates exacerbate the non-target Ascomycete fungi, and other fungi producing an ephytiotic outbreak of much greater magnitude than the infections occurring without phosphonate treatment. This phenomenon is known as pathological acerbatation.

In the past, phosphates were not viewed as a solution to pathological acerbatation of Ascomycete fungal infections. This is because phosphates are viewed primarily as a fertilizer with only limited, or even detrimental, fungicidal properties. For example, U.S. Pat. No. 5,514,200 teaches that phosphate fertilizers inhibit beneficial symbiosis between plant roots and mycorrhizal fungi, and further promote bacterial and fungal growth in the rhizosphere, including the growth of pathogenic fungi and other small soil-borne organisms. (Col. 2, lines 18-28). Phosphates have also been considered to be a competitive inhibitor for phosphonate assimilation, thus inhibiting the ability of phosphonates to protect against fungus attack. See, Pegg, K. G. and deBoer, R. F., "Proceedings of the Phosphonic (Phosphorous) Acid Work Shop," *Australasian Plant Pathology*, Vol. 19 (4), pp. 117 and 144, 1990. Yet further, phosphonates and phosphates were believed to be "biological strangers," with the presence of phosphonates or its esters, exerting little or no influence on enzyme reactions involving phosphates. Robertson, H. E. and Boyer, P. D., "The Biological Inactivity

of Glucose 6-phosphonate. Inorganic Phosphites and Other Phosphites." *Archives of Biochemistry and Biophysics*. 62 pp. 380-395 (1956).

Accordingly, the requirements for a successful phosphonate-based fungicide depend on the elimination of the phosphonate-induced pathological ascription of Ascomycete fungical infections.

Moreover, the prior art teaching that phosphates and phosphonates are "biological strangers" is relevant to the lack of teaching of use of a composition of both for any agricultural use.

#### SUMMARY OF THE INVENTION

The present invention addresses the problems outlined above, and provides an improved anti-fungicidal composition for plants that contains, as active ingredients, fungicidally effective amounts of both phosphonates and phosphates. According to the present invention, it has been discovered that the application to a plant of the inventive phosphonate/phosphate composition substantially eliminates pathological ascription of Ascomycete fungi, while at the same time, provides a means to control Phycomycetes and Ascomycetes and other fungi with a single product.

Thus, an object of present invention is to provide a fungicidal composition for protection for plants against fungal infection, especially Phycomycetes and Ascomycetes.

Another object of the invention is to provide such anti-fungal protection with a single product that upon application does not cause pathological ascription of Ascomycetes infections.

A further object of the invention is to provide a method of treating plants and to provide anti-fungal protection in plants against attack by Phycomycetes, Ascomycete and other fungi and bacteria.

A yet further object of the invention is to provide an anti-fungal composition for treating plants that is environmentally safe, inexpensive to use and has low mammalian toxicity.

These and other objects of the invention are attained by the invention disclosed below. According to the invention, anti-fungicidal compositions for the protection of plants, especially citrus and fruit trees and vines against fungus attack, preferably contain as an active material a fungicidally effective amount of at least a first salt formula selected from the group consisting of  $\text{KH}_2\text{PO}_4$ ,  $\text{K}_2\text{HPO}_4$ , and  $\text{K}_3\text{PO}_4$ , and at least a second salt selected from the group consisting of  $\text{KH}_2\text{PO}_4$ ,  $\text{K}_2\text{HPO}_4$  and  $\text{K}_3\text{PO}_4$ , in a mixture with an agriculturally acceptable carrier.

The composition preferably comprises an aqueous solution wherein each salt is present in solution from about 20 millimole to about 5% vol/vol.

According to another aspect of the invention, the amount of the first salt is one part by weight and the amount of the second salt is between 0.001 and 1.000 parts by weight.

Phosphonate salts useful in the practice of the invention also include those organic and inorganic salts taught by U.S. Pat. Nos. 4,075,324 and 4,119,724 to Thizy et al., (see, e.g., col. 1, ln. 51-69 through col. 2, ln. 1-4).

The present invention, in another aspect, also has been found to be effective as a growth stimulator or fertilizer for plants, and addresses the problems in the art with regard to finding effective fertilizers. Thus, the present invention provides a means for applying a single product to plants which is both an effective fungicide and an effective fertilizer.

It is therefore an object of this aspect of the invention to present a composition and method of use which functions as a fertilizer for plants.

A further object of this aspect of the invention is to function as a fertilizer which provides substantial growth response results.

Another object of this aspect of the invention is to function as a fertilizer which is ecologically and human compatible, is economical, and is efficient.

These and other objects, features and advantages of the invention will become more apparent with reference to the accompanying specification and claims.

#### A DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The following examples set for preferred concentrations and techniques for formulation thereof, as well as methods of application and use and test results demonstrating the efficacy of the inventive concentration in protecting plants against attack by Ascomycete and Phycomycete fungi. It is to be understood, however, that these Examples are presented by way of illustration only and nothing therein shall be taken as a limitation upon the overall scope of the invention. The specific components tested in the Examples were prepared and applied as follows.

##### Method of Preparation

A. Potassium Phosphonate ( $\text{KH}_2\text{PO}_4$ ) Aqueous Solution.  $\text{H}_3\text{PO}_3$  is produced by the hydrolysis of phosphorus trichloride according to the reaction:  $\text{PCl}_3 + 3\text{H}_2\text{O} \rightarrow \text{H}_3\text{PO}_3 + 3\text{HCl}$ . The HCl is removed by stripping under reduced pressure and the phosphonic acid ( $\text{H}_3\text{PO}_3$ ) is sold as a 70% aqueous solution.

The phosphonic acid is then neutralized in aqueous solution by potassium hydroxide according to the reaction:  $\text{H}_3\text{PO}_3 + \text{KOH} \rightarrow \text{KH}_2\text{PO}_3 + \text{H}_2\text{O}$  to about pH 6.5 and to produce 0-22-20 liquid weighing 11.15 lbs./gal. This solution is commercially available and is sold under the trademark "Phos-Might" by Foliar Nutrients, Inc., Cairo, Ga. 31728.

B. Potassium Phosphate ( $\text{K}_2\text{HPO}_4$ ) Aqueous Solution. Mono potassium phosphate (0-51.5-34) is reacted with 45% potassium hydroxide in aqueous solution to produce dipotassium phosphate by the following reaction: This solution is commercially available and is sold under trademark "K-Phos" by Foliar Nutrients, Inc., Cairo, Ga. 31724.

$\text{KH}_2\text{PO}_4 + \text{KOH} \rightarrow \text{K}_2\text{HPO}_4 + \text{H}_2\text{O}$  with a product density of 1.394 at 20° C. and a solution pH of 7.6 producing a 0-18-20 analysis.

C.  $\text{KH}_2\text{PO}_4/\text{K}_2\text{HPO}_4$  Solution. Varying amounts of each compound ( $\text{K}_2\text{HPO}_4/\text{KH}_2\text{PO}_4$ ;  $\text{K}_2\text{HPO}_4$ ; or  $\text{KH}_2\text{PO}_4$ ) in aqueous solution are combined at rates ranging from 20 millimole to 5% vol/vol., depending on crop host and the pathogen complex and level of infection.

##### Method of Application

The preferable method of application is foliar, either by ground or aerial equipment, but is not limited to that method alone. Injection or soil applications, for example, could also be efficacious depending on specific crops and pathogens.

The inventive compositions have utility on fruit crops, agronomic crops, ornamentals, trees, grasses, vegetables, grains, and floricultural crops, as well as, some aquatic crops including water cress.

The fungicidal properties of the compounds according to the invention are various, but are particularly interesting in the case described in the following examples:

Examples 1-5 exemplify a portion of these applications. In Examples 1-4, fungicidal treatments were applied to ornamentals, citrus and vegetables. In each of Examples

1-4, treatments were applied as a one gallon solution by a backpack sprayer, maintained at about 60 psi, in sufficient quantities of water to achieve thorough coverage.

All treatments were applied to the appropriate number of experimental units assigned in a randomized complete block (RCB) design replicated four times. Example #5 was a pre-harvest fungicidal spray evaluation on "Nova" tangelos.

As used in the examples, "percent infection" means percent of leaves that exhibit fungus lesions. "Phytotoxicity" means number crop injury to leaves that fell off the plant following the application of the solution.

The Ascomycete fungi were the subjects of testing in Examples 1 through 5 and are all members of the Ascomycete family.

#### EXAMPLE NO. 1

DogwoodPowdery Mildew Fungicide Trial Trail  
Ridge Nursery, Keystone Hts., Fl.

The compounds according to the invention are studied for the effect on the powdery mildew (*Oidium* Spp.), which is responsible for foliar infections in dogwood.

Potassium phosphonate and potassium phosphate solutions were applied in compositions as set forth in Table 1 below. An average of 5 six-inch pots per experimental unit with 4 repetitions in a randomized complete block ("RCB") design were considered. The solutions were applied to Dogwood (*Cornus Florida* Var. "Weaver"). The application of the compositions were made in Apr. 25, 1996, May 8, 1996, and May 23, 1996. The effects of the various compositions were rated on May 30, 1996.

Table 1 shows that when a potassium phosphonate solution (containing no appreciable amount of phosphate) is applied to dogwood, pathological acerbation of the Ascomycete fungus occurs in 100 percent of the dogwood leaves, in contrast to the control, which exhibited only 30 percent infection. The inventive composition that combine potassium phosphate and potassium phosphonate showed a complete elimination of the pathological acerbation phenomenon, and in fact, dropped the amount of infection by about 20 percent.

TABLE 1

TREATMENT	RATE/ 100 gal	% INFECTION	PHYTO- TOXICITY
1) POTASSIUM PHOSPHONATE SOLUTION	1%	100	0
2) POTASSIUM PHOSPHATE SOLUTION	1%	0	0
3) POTASSIUM PHOSPHONATE SOLUTION	1%	10	0
+ POTASSIUM PHOSPHATE SOLUTION	+	+	0
4) POTASSIUM PHOSPHATE SOLUTION	2%	0	0
5) CONTROL	—	30	0

#### EXAMPLE NO. 2

Shumard Oak/Powdery Mildew Fungicide Trial Trail  
Ridge Nursery, Keystone Hts., Fl.

In Example No. 2, the inventive compositions were tested for effectiveness against the powdery mildew (*Phyllactinia corylea*) that infects shumard oak (*Quercus shumardii*). In Example No. 2, an average of ten 3-gallon plots per experimental unit with 4 repetitions in a randomized complete block design were examined.

When only potassium phosphonate solution was applied, the percentage of infection increased to 40 percent, compared to a 20 percent infection in the control, indicating a pathological acerbation of the Ascomycete fungi. When the inventive composition including potassium phosphonate and potassium phosphate was applied, the infection was completely eliminated.

TABLE 2

TREATMENT	RATE/ 100 gal	% INFECTION	PHYTO- TOXICITY
1) POTASSIUM PHOSPHONATE SOLUTION	1%	40	0
2) POTASSIUM PHOSPHATE SOLUTION	1%	0	0
3) POTASSIUM PHOSPHONATE SOLUTION	1%	0	0
+ POTASSIUM PHOSPHATE SOLUTION	+	+	0
4) POTASSIUM PHOSPHATE SOLUTION	2%	0	0
5) CONTROL	—	20	0

#### EXAMPLE NO. 3

Citrus Alternaria Fungicide Trial Kerr Center, Vero  
Beach, Fl.

In Example No. 3, the inventive composition was tested for effectiveness in citrus trees (*Alternaria citri*) that were infected with the fungi.

As used in Table No. 3 below, "% Y.L.D." means percent young leaf drop, and "% Y.F.D." means percent young fruit drop. % Y.L.D. and % Y.F.D. were determined by examining 4 terminals/tree with 4 repetitions in a randomized complete block design. The date on which the compositions were applied were Mar. 21, 1996. The compositions were rated on Apr. 2, 1996. When only potassium phosphonate solutions were applied, % Y.L.D. and % Y.F.D. increased from 6.2 and 1.5 to 23.9 and 37.9, respectively, indicating pathological acerbation of the Ascomycete fungi. Application of the inventive composition not only eliminated the acerbation, but showed an improvement in Y.L.D. and Y.F.D.

TABLE 3

TREATMENT	RATE/ 100 gal	% Y.L.D.	% Y.F.D.	PHYTO- TOXICITY
1) POTASSIUM PHOSPHATE SOLUTION	0.5%	5.2	3.8	0
2) POTASSIUM PHOSPHATE SOLUTION	1%	2.5	2.5	0
3) POTASSIUM PHOSPHATE SOLUTION	2%	1.5	1.0	0
4) POTASSIUM PHOSPHONATE SOLUTION	1%	23.9	37.5	0
5) POTASSIUM PHOSPHATE SOLUTION	0.5%	2.2	3.7	0
+ POTASSIUM PHOSPHONATE SOLUTION	+	+	+	0
6) CONTROL	—	6.2	1.5	0

#### EXAMPLE NO. 4

Carrot/Alternaria Fungicide Trial

In Example No. 4, carrot plots were inoculated with *Alternaria dauci* fungi. The plot sizes were single rows X 25

feet X 4 repetitions in a RCB design. The dates that compositions were applied were Feb. 2, 9, 15, 22, and Mar. 8, 14, 22, and 28, 1996. The fungi infections were rated on Apr. 5 and Apr. 23, 1996. The second rating was 25 days after the last fungicide application. The test took place at Sanford, FL.

Application of the inventive solutions including potassium phosphonate and potassium phosphate improved the extent of infection from that otherwise occurring in the control carrots. Although the solution making use of only potassium phosphonate caused a slight improvement from the infection occurring in the control, it was substantially less than that associated with the inventive composition.

Also shown in Example No. 4 is a comparison of the effectiveness of the inventive composition to other fungicides, including Cu-Alexin and Fe-Alexin. This test demonstrates that the inventive composition is as effective as other well known fungicides, but without being as environmentally toxic.

TABLE 4

TREATMENT	RATE/100 GAL.	AVG % INFECTION	
		4/5/96	4/23/96
1) POTASSIUM PHOSPHATE SOLUTION	1%	6.9	8.2
2) POTASSIUM PHOSPHONATE SOLUTION	1%	18.7	28.8
3) POTASSIUM PHOSPHATE SOLUTION + POTASSIUM PHOSPHONATE SOLUTION	0.5% + 0.5%	8.9	10.7
4) Cu-ALEXIN	0.2 lb at	8.8	11.6
5) Fe-ALEXIN	0.2 lb at	12.7	12.9
6) CONTROL	—	23.0	34.8

### EXAMPLE NO. 5

Citrus Preharvest Spray Trials Kerr Center, Vero Beach, Fl.

In Example No. 5, twenty-two fruits, each from five navel tangelo trees, were randomly selected and marked. The fruits were scuffed with an emery board and then sprayed with the compositions set forth below in Table 5, with five treatments on the same day. Seven days later, the fruit was picked and stored for two weeks in sealed white plastic bags, then examined for penicillium mold.

The degree of infection was rated using following scores: 0=no infection, 1=light infection (less than 30% coverage), 2=severe infection (100% coverage). The degree of infection is the mean of scores from 22 fruit.

TABLE 5

TREATMENT	RATE	DEGREE OF INFECTION	# ROTTEN FRUIT	PHYTO- TOXICITY
1) POTASSIUM PHOSPHONATE SOLUTION	1%	1	9	0
2) POTASSIUM PHOSPHONATE SOLUTION	2%	0.91	12	0

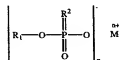
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TABLE 5-continued

TREATMENT	DEGREE OF INFECTED RATE	ROTTEN FRUIT	PHYTO- TOXICITY
3) POTASSIUM PHOSPHATE SOLUTION	1%	0	0
4) POTASSIUM PHOSPHATE SOLUTION	0.5%	0.27	3
+ POTASSIUM PHOSPHONATE SOLUTION	0.5%		
5) CONTROL	—	1.41	12

The above Examples demonstrate that the inventive compositions are useful in protecting plants against attack by Phycomycete, Ascomycete and other fungi and bacteria with the application of one solution.

It will also be appreciated that compositions for controlling Phycomycete and Ascomycete fungi diseases in plants may also contain phosphate and phosphonate compounds comprising a fungicidally effective amount of at least a first salt having the following formula:



And a second salt having the following formula:



Where R<sub>1</sub> is selected from group consisting of H, K, an alkyl radical containing from 1 to 4 carbon atoms, halogen-substituted alkyl or nitro-substituted alkyl radical, an alkenyl, halogen-substituted alkenyl, alkynyl, halogen-substituted alkynyl, alkoxy-substituted alkyl radical, ammonium substituted by alkyl and hydroxy alkyl radicals;

$R_2$  and  $R_3$  are selected from a group consisting of H and K:

Me is selected from a group consisting of K, alkaline earth metal cations, aluminum atom; ammonium cation; and n is a whole number from 1 to 3, equal to the valence of Me.

It will be appreciated that foliar applications of the inventive compositions will be effective as a common agricultural practice to control root pathogens caused by Phytophthora, Phythium, and foliar infections caused by Plasmodora.

It will also be appreciated that the inventive compositions will have biocidal and arthropod pest control activity, and also have fertilizer effects, in plants. (See e.g., U.S. Pat. Nos. 5,206,228, 5,133,891 and 5,514,200).